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Comment on "The shape and composition of interstellar silicate grains"

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"The shape and composition of interstellar silicate grains"

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In the paper entitled "The shape and composition of interstellar silicate grains" (A & A, 462, 667-676 (2007)), Min *et al.* explore non-spherical grain shape and composition in modeling the interstellar 10 and 20 μm extinction features. This progression towards more realistic models is vitally important to enabling valid comparisons between dust observations and laboratory measurements. Min *et al.* proceed to compare their model results with GEMS (glass with embedded metals and sulfides) from IDPs (interplanetary dust particles) and to discuss the nature and origin of GEMS. Specifically, they evaluate the hypothesis of Bradley (1994) that GEMS are interstellar (IS) amorphous silicates. From a comparison of the mineralogy, chemical compositions, and infrared (IR) spectral properties of GEMS with their modeling results, Min *et al.* conclude: "GEMS are, in general, not unprocessed leftovers from the diffuse ISM." This conclusion is based, however, on erroneous and incomplete GEMS data.

It is important to clarify first that Bradley (1994) never proposed that GEMS are *unprocessed* leftovers from the diffuse ISM, nor did he suggest that individual sub-nanogram mass GEMS are a representative sampling of the enormous mass of silicates in the diffuse ISM. Bradley (1994) simply showed that GEMS properties are consistent with those of IS amorphous silicates. It is widely accepted that circumstellar outflows are important sources of IS silicates, and whether GEMS are processed or not, the circumstellar heritage of some has been rigorously confirmed through measurements of non-solar oxygen (O) isotope abundances (Messenger *et al.*, 2003; Floss *et al.*, 2006). Keller *et al.* (2000) assert that even GEMS without detectable O isotope anomalies are probably also extrasolar IS silicates because they are embedded in carbonaceous material with non-solar D/H isotopic composition. (Much of the silicate dust in the ISM may be isotopically homogenized (Zhukovska *et al.*, 2007)). Recent measurements show that the elemental compositions of GEMS with non-solar isotopic compositions are "remarkably similar" to those with solar isotopic compositions (Keller & Messenger, 2007). About 80% of all isotopically anomalous IS silicates identified to date are GEMS with detectable and variable O isotopic memories of a circumstellar ancestry (Messenger, 2007).

Bradley (1999) proposed that GEMS are IS silicates from "a presolar interstellar molecular cloud, presumably the local molecular cloud from which the solar system formed." Although based on incorrect data (detailed below), Min *et al.* propose that most GEMS actually formed in the presolar molecular cloud, and they further propose that none of them are IS silicates. IS silicate sources include molecular clouds, circumstellar outflows, supernovae, and even recently discovered black hole winds (Molster & Waters;

2003; Jones, 2005; Zhukovska *et al.* 2007; Markwick-Kemper *et al.* 2007). The average IS 10 μm extinction feature observed along lines of sight towards the galactic center (modeled by Min *et al.*) presumably provides a good average for IS silicates, but it cannot distinguish amorphous silicates originating in the presolar molecular cloud from amorphous silicates originating in other interstellar molecular clouds or indeed other sources of amorphous IS silicates. Even if most GEMS accreted in the presolar molecular cloud, then they must also be representatives of some portion of the IS amorphous silicate population. Laboratory heating experiments indicate it is highly unlikely that GEMS were modified in a protoplanetary accretion disk environment (Brownlee et al. 2005).

In claiming that the properties of GEMS are inconsistent with their IS grain modeling results, Min *et al.* make the following mischaracterizations of the bulk properties of GEMS:

(1) "Preliminary observations indicate that iron sulfide inclusions are located preferentially at the edge of grains (Keller *et al.*, 2005)." Min *et al.* cite this experimental evidence to link GEMS formation to the presolar molecular cloud environment of the solar nebula. However, the supporting reference they cite (Keller *et al.*, 2005) does not show that sulfides are located at the outer edges of GEMS. While there may be examples of GEMS with sulfides located preferentially at the edges, published data on GEMS show sulfides uniformly dispersed throughout their interiors (e.g. Dai & Bradley, 2005), as well as sulfides located preferentially within their interiors (e.g. Bradley, 1994; Bradley *et al.*, 1997; Westphal & Bradley, 2004). Sulfides are not located preferentially at the outer edges of GEMS.

(2) "The average GEMS silicate has (Mg+Fe)/Si ~ 0.7 (Keller and Messenger, 2004), much lower than we derive…." Keller and Messenger, 2004 did not report on the compositions of the amorphous (glassy) silicate matrices in GEMS.

(3) "This gives O/Si ~ 2.7 in the GEMS silicates ". Min *et al.* did not measure the O/Si ratio in GEMS, and neither did Keller & Messenger (2004). Instead they estimated this ratio by assuming a crystalline silicate (pyroxene) O/Si stoichiometry. However, stoichiometry cannot be assumed in glasses and instead must be measured directly (Keller & MacKay, 1997). Measured average bulk O/Si ratios reported in the literature for GEMS, where O and Si are entirely in the glass, range from 3.6 to 4.0 (Bradley, 1994; Bradley & Ireland, 1996). These values are consistent with O/Si ~3.5 calculated for IS silicates by Min *et al.* They fail to cite references that measured the O/Si ratio.

(4) "the spectral position of the maximum absorption reported for GEMS is around 9.3 μm (Bradley *et al.*, 1999a), while it is around 9.7 μm in the ISM." In fact, Bradley *et al.* 1999a report absorption maxima ranging from 9.2 to 9.8 μm. Bradley *et al.* 1999b (also referenced in Min *et al.*) report absorption maxima in GEMS-rich specimens ranging from 9.3 to 10.4 μm, and more importantly, an absorption maximum in a rare "pure" GEMS specimen at 9.7 μm, again consistent with the 9.7 μm feature of IS silicates reported by Min *et al.*

In summary, Min *et al.* conclude from their modeling of the shape and composition of IS silicates that the properties of GEMS are generally inconsistent with those of IS silicates. First, it has been rigorously confirmed via ion microprobe measurements that some GEMS are indeed presolar IS silicates. Second, regardless of whether GEMS, or components of GEMS, originated in presolar circumstellar outflows or a presolar molecular cloud they are all IS silicates. Third, key GEMS data reported in Min *et al.* are inaccurate. Had complete isotopic, chemical, mineralogical and infrared (IR) spectral properties of GEMS been considered, Min *et al.* may have concluded that the properties of GEMS, although not an exact match, are generally consistent with those of amorphous silicates in the ISM.

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